

D-1390

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

P18477

* TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

09/402482

INTERNATIONAL APPLICATION NO.

PCT/DE97/02024

INTERNATIONAL FILING DATE

09 September 1997

PRIORITY DATE CLAIMED

14 April 1997

TITLE OF INVENTION

DEVICE FOR INSPECTING TEST OBJECTS AND THE USE THEREOF

APPLICANT(S) FOR DO/EO/US

Christoph GROHMANN, Randolph HANKE and Detlef HAFER

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information.

1. ☒ This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(C)(2))
 - a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A Translation of the International Application into English (35 U.S.C. 371 (c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3))
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
"EXECUTED"
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (U.S.C. 371(c)(5)).
- Items 11. to 16. below concern other document(s) or information included:
 11. ☐ An information Disclosure Statement under 37 CFR 1.97 and 1.98.
 12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
 13. ☐ A FIRST preliminary amendment.
☐ A SECOND or SUBSEQUENT preliminary amendment.
 14. ☐ A substitute specification.
 15. ☐ A change of power of attorney and/or address letter.
 16. ☒ Other items or information:

International Application as published in German (cover sheet).
PCT/ISA/220 (in German).
PCT/ISA/210 (in German).
PCT/IPEA/416 (in German).
PCT/IPEA/409 International Preliminary Examination Report in German (with four sheets of Amended Pages).
Claim of Priority.

420 Rec'd PCT/PTO 13 OCT 1999

APPLICATION NO. (If known, see 37 CFR

09/402482

INTERNATIONAL APPLICATION NO.

PCT/DE97/02024

ATTORNEY'S DOCKET NUMBER

P18477

7. ☒ The following fees are submitted:

Basic National Fee (37 CFR 1.492(a)(1)-(5)):

Search report has been prepared by the EPO or JPO. \$ 840.00

International preliminary examination fee paid to USPTO (37 CFR 1.482). \$ 670.00

No international preliminary examination fee paid to USPTO (37 CFR 1.482) but
international search fee paid to USPTO (37 CFR 1.445(a)(2)) \$ 760.00Neither international preliminary examination fee (37 CFR 1.482) nor
international search fee (37 CFR 1.445(a)(2)) paid to USPTO. \$ 970.00International preliminary examination fee paid to USPTO (37 CFR 1.482) and all
claims satisfied provisions of PCT Article 33(2)-(4). \$ 96.00

ENTER APPROPRIATE BASIC FEE AMOUNT =

\$ 840.00

Surcharge of \$130.00 for furnishing the oath or declaration later than ___ 20 ___ 30
months from the earliest claimed priority date (37 CFR 1.492(e)).

\$ 0.00

Claims	Number Filed	Number Extra	RATE	\$	
Total Claims	- 20 =		X \$18.00	\$	0.00
Independent Claims	- 3 =		X \$78.00	\$	0.00
Multiple dependent claim(s) (if applicable)			+ \$260.00	\$	0.00

TOTAL OF ABOVE CALCULATIONS =

\$ 840.00

Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also
be filed. (Note 37 CFR 1.9, 1.27, 1.28)

\$ 0.00

SUBTOTAL =

840.00

Processing fee of \$130.00 for furnishing the English translation later than ___ 20 ___ 30
months from the earliest claimed priority date (37 CFR 1.492(f)).

+

0.00

Extension of Time fee in the amount of \$

+

0.00

TOTAL NATIONAL FEE =

840.00

Fee for recording the enclosed assignment (37 CFR 1.21(h). The assignment must be
accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property

+

40.00

TOTAL FEES ENCLOSED =

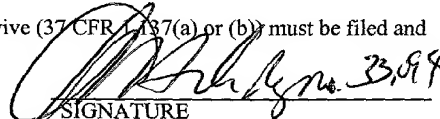
880.00

Amount to be
refunded \$

Charged \$

a. ☒ A check in the amount of \$880.00 to cover the above fees is enclosed.b. ___ Please charge my Deposit Account No. ___ in the amount of \$ ___ to cover the above fees.
A duplicate copy of this sheet is enclosed.c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to
Deposit Account No. 19-0089. A duplicate copy of this sheet is enclosed.NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.487(a) or (b)) must be filed and
granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Neil F. Greenblum
GREENBLUM & BERNSTEIN, P.L.C.
1941 Roland Clarke Place
Reston, VA 20191
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SIGNATURE
Neil F. Greenblum
NAME28,394
REGISTRATION NUMBER

TRANSMITTAL TAL

PI8477.A01

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants :	Christoph GROHMANN et al.)	
)	Group Art Unit: Unknown
Appln. No. :	09/402,482)	
)	Examiner: Unknown
Filed :	September 9, 1997)	
)	
For :	DEVICE FOR INSPECTING TEST)	
	OBJECTS AND USE THEREOF)	

**PRELIMINARY AMENDMENT AND COVER LETTER
SUBMITTING AMENDED PAGES OF APPLICATION**

Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

Enclosed please find a copy of the International Preliminary Examination Report - Form PCT/IPEA/409 (hereinafter "Report"), in German and English, which was drawn on pages of description 1, 2, 4 - 13, and the drawings as originally filed, and pages 3a and 3b of the description and claims 1 - 13 as filed on March 1, 1999 (01.03.99), and includes as an Annex amended pages 3a and 3b of description and claims 1 - 13 (in German and English). Also enclosed is a copy of the English language version of the Form PCT/IB/338.

Based upon the submission of amended sheets of description and claims, Applicants respectfully request examination on the merits of the application containing amended pages of description 3a and 3b (in place of originally filed page 3), and amended claims 1 - 13 (in place of originally filed claims 1 - 13).

Moreover, prior to the examination of the above-identified application including replacement claims 1 - 13, amendment of claims 3, 5, 6, 7, 9, 10, and 12 as follows, is respectfully requested to

remove multiple dependent claims.

IN THE CLAIMS

Please amend replacement claims 3, 5, 6, 7, 9, 10, and 12 as follows:

Claim 3, line 1, please delete "or 2".

Claim 5, line 1, please change "one of claims 1 to 4" to ---claim 1---.

Claim 6, line 1, please change "one of claims 1 to 5" to ---claim 1---.

Claim 7, line 1, please change "one of claims 1 to 6" to ---claim 1---.

Claim 9, line 1, please change "one of claims 1 to 8" to ---claim 1---.

Claim 10, line 1, please change "one of claims 1 to 9" to ---claim 1---.

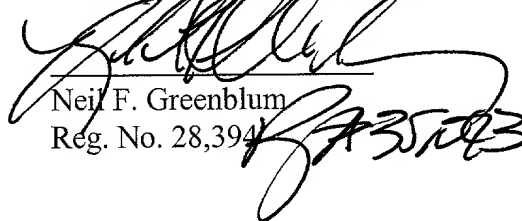
Claim 12, line 1, please delete "if dependent on claim 4".

REMARKS

Entry of the foregoing replacement sheets and amendment to the claims upon which the International Preliminary Examination Report is based is respectfully requested.

Should there be any questions, the Examiner is invited to contact the undersigned at the below listed number.

Respectfully submitted,
Christoph GROHMANN et al.


Neil F. Greenblum
Reg. No. 28,394

November 8, 1999
GREENBLUM & BERNSTEIN, P.L.C.
1941 Roland Clarke Place
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VERIFICATION OF TRANSLATION

I, AMY JACOBSON

of 1941 Roland Clarke Place
Reston, VA 20191

declare that I am well acquainted with both the German and English languages, and that the attached is an accurate translation, to the best of my knowledge and ability, of the German language Patent Application No. PCT/DE97/02024, filed September 9, 1997.

Signature


AMY JACOBSON

Date

10/29/99

Device for Inspecting Test Objects and Use Thereof

The present invention relates to a device for the inspection of test objects with the characteristics of the preamble to claim 1 as well as to the use of the device for X-ray inspection of soldered joints on printed circuit boards and/or loaded printed board assemblies and particularly to the use of the device for completely automatic 100% X-ray inspection of soldered joints on printed circuit boards and/or loaded printed board assemblies.

A device with the characteristics of the preamble to claim 1 is known from European printed Patent Specification No. 0 236 001 B1. In this printed specification, systems for two-dimensional, completely automatic X-ray inspection of switch plates and board assemblies are described. Because the X-ray source and X-ray detector used have a small field of view in comparison to the horizontal extent of the area of the test object to be tested, the examination of the entire area of the test object to be examined is conducted in that the test object is moved along the X-Y plane. Thus, the known system has a multiple axis positioning system in order to receive board assemblies and to position them appropriately.

However, the known system has the following disadvantages. For one, the design of the multiple axis positioning system is very costly because, in addition to the XY axis of movement, devices must be provided for receiving and ejecting the board assemblies. Because the test object is located between the X-ray source and detector, the corresponding positioning system must also be located in the area between the X-ray source and detector. Thus, a great deal of space is needed, making the entire device voluminous. Furthermore, during the movement of the board assemblies at high speeds, the components and especially the soldered joints are stressed because of the laterally acting forces. This especially affects high attached components, but also components that, because of their structure, allow only soldered joints that are lightly wetted.

The soldered joints can be damaged by this stress. Such damage will not

necessarily become apparent immediately after the acceleration or braking process. It is just as conceivable for an imperceptible defect to appear in the soldered joints immediately after the acceleration or braking process that does not lead to a failure of the soldered joints until after a somewhat longer time has elapsed, e.g., in conjunction with temperature fluctuations or vibrations.

A further disadvantage of the known system consists of the fact that it is only suitable for two-dimensional examination of test objects. It is not designed for examining individual components on the board assembly three-dimensionally.

Furthermore, the problem arises that, when board assemblies whose masses differ widely from one another are to be examined, different forces must be applied in order to move them within the predetermined cycle period. Accordingly, exact adjustment of the operating parameters is necessary for each type of board assembly.

Moreover, movement of the board assembly during the examination process causes the board assembly to vibrate up and down. As a result, therefore, waiting times for cessation of vibrations are necessary and distance measurements to the board assemblies cannot be conducted with a very great degree of accuracy. Furthermore, the vibration behavior of the board assemblies during the long illumination time of the camera (> 200 ms) leads to less than optimal picture sharpness.

The problem of a coordinated relative movement between the test object, X-ray source, and detector has furthermore been discussed in numerous patent documents that relate to improvements of tomosynthesis processes.

Tomosynthesis involves a three-dimensional X-ray imaging process in which a plurality of X-ray pictures are

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taken at various relative positions of the test object and the X-ray source in order to form the cross-sectional image of a desired plane inside the three-dimensional object on the detector. In contrast to this, the problem is handled in this class-defining X-ray inspection system in a simple X-ray radiograph process without layer resolution covering the entire region of a test object to be examined with an X-ray source and a detector, each of which has a small field of view in comparison to the horizontal extent of the region of the test object to be examined.

The known tomosynthesis methods which, for example, are known from the publications of S.F. Buchele, H. Ellinger, F. Hopkins in Materials Evaluation 48, May 1990; R.J. Kruse, R.H. Bossi in Review of Progress in Quantitative Nondestructive Evaluation, Vol. 10B, 1991; D.G. Grant in IEEE Transactions on Biomedical Engineering 19, Jan. 1972; U.E. Ruttimann, X. Qi, L. Weber in Medical Physics 16(3), May/June 1989, are based on the principle of moving X-ray beam tubes and detectors while the object to be examined remains stationary. Because the highly precise positioning of X-ray beam tubes entails numerous problems relating to the degree of accuracy to be maintained and the speed of the measuring process and requires a complicated mechanical structure of the measuring device, later experiments have focused on further simplification of the measuring system, on a higher degree of accuracy, and a higher measuring speed.

Thus, German Patent Application P 42 35 183, filed by a co-applicant of the current application, describes a process for creating layer images of a three-dimensional object in which the X-ray beam source and the detector remain stationary while the object is moved.

A similar process is known from European Patent Application EP-A-0 683 389, in which a laminographic examination system with a radiation source, a sensor device, and a device for moving the test object is described. The test object is moved so that it assumes a plurality of different positions between the radiation source and the sensor device. Alternately, the radiation source and sensor device can also be moved on a

Art. 34

1871	1872	1873	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279</
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MODIFIED SHEET

Further concepts for solving the problems mentioned above are based on a realization of the X-ray beam tubes in which the electron beam activating the X-ray beam is deflected by deflection coils.

5 Thus, US Patent No. 5 097 492 describes a tomographic examination system in which the electron beam is deflected by appropriately actuated deflection coils in such a way that the X-ray beam thus produced makes a circular movement on the object to be examined in order to achieve in this manner the cross-sectional images necessary for the tomosynthesis process.

10

 Furthermore, US Patent No. 5 259 012 describes another tomographic examination system in which, on the one hand, the electron beam makes a circular movement on the target material as a result of the coordinated deflection by means of deflection coils so that the X-ray beam thus produced makes a circular movement on the object to be examined in order to achieve in this manner the cross-section images necessary for the tomosynthesis process. On the other hand, however, another additional direct current is applied to the deflection coil in the X or Y direction so that the resulting X-ray beam is pivoted in the X-Y plane and the field of view of the X-ray focus can be moved within the X-ray source.

20

 However, in applying the mechanism described in US Patent No. 5 259 012 to testing the entire area of a test object to be examined, the problem arises that the horizontal extent of the X-ray tube must be greater than the area of the test object to be examined. On the one hand, this leads to a very voluminous testing system and also leads to problems when test objects are used which have very differently sized areas to be examined. Furthermore, the problem arises that, because the X-ray source is actually tipped and not moved, the beam diameter of the X-ray beam varies according to whether a central section or an edge section is being tested. As a result, the accuracy of the measurement varies in the absence of electronic control of the X-ray focus.

30

A further disadvantage of this system consists of the fact that, because the

deflection coils must be correspondingly controlled, an expensive and complicated control of the X-ray tubes is necessary.

Thus, the object of the present invention is to improve the device known from European Patent No. 0 236 001 B1 in such a way that it becomes more compact and allows a faster and truly non-destructive testing of the entire area of the test object to be examined.

According to the present invention, the object is attained by means of the characterizing portion of claim 1. Furthermore, according to the present invention, the use of the device according to the invention is provided in claim 10. The preferred embodiments are the object of the subclaims.

The present invention is based on the surprising realization that, contrary to the widespread prevalent opinion in the current field of application, it is possible to move the X-ray beam source within the X-Y plane with a high degree of accuracy, i.e., with an accuracy of down to approximately 5 μm , and at a high speed in spite of its large mass of about 10 to 20 kg.

One reason this is possible is that a less heavy X-ray beam tube without a vacuum pump or cooling is used. Such an X-ray beam tube can be used in a satisfactory manner because, for the purposes of the current invention, as will be explained in the following, an X-ray tube with a larger focal spot diameter of greater than 10 μm , preferably up to 40 μm , can be used.

Furthermore, only the X-ray tube itself and the high voltage element containing the power supply are moved when the X-ray beam tubes are moved, while the control device for changing the working voltage or output is not moved. Nevertheless, the total mass of the mobile parts is approximately 13.5 kg.

Also, the inventors of the present invention developed a special device for moving

the X-ray beam tube and the detector horizontally in order to ensure that these components can be moved with great accuracy and at high speeds despite their large mass. This special device is based on an appropriate combination of highly precise axial components, measuring systems, and a high-performance position control system.

5

The following advantages can thus be achieved by the device according to the invention:

- 10 1. The device according to the invention allows a completely non-destructive examination of the areas to be examined. More precisely, large accelerations of the board assembly in the device according to the invention are prevented so that no damage to the soldered joints occurs as a result of acceleration or braking processes of the board assemblies. Furthermore, it is not necessary to fix the board assemblies inside the mounting so that they do not move off center during acceleration/braking. The
- 15 disadvantage of such a fixing is namely that the edge regions of the board assemblies, particularly the conductors located in the edge regions, can also be damaged as a result of fixing the board assemblies, for example, when the board assemblies are clamped into a mounting device. A further disadvantage is that the fixing carries the danger that the board assemblies could slip off-center in the mounting device as a result of the strong
- 20 forces during acceleration or braking, which would cause damage to the conductors at the edges and force the inspection to be aborted due to a change of position.

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Because the board assemblies need not absorb any acceleration or braking processes in the present invention, this danger is safely prevented.

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2. Furthermore, distance measurements at the stationary position of the board assembly to be examined can be conducted with increased accuracy, e.g., by means of a laser triangulation process.

3. Since always components with a constant mass are moved, namely the X-ray beam source and the detector, no adaptation of the moving mechanism to the board

assembly to be examined is necessary, in contrast to the known device. Thus, increased accuracy, greater speed, and greater flexibility in the examination of board assemblies of different masses are achieved.

5 4. Because of the substantially smaller areas of movement, the construction of the device according to the invention achieves a substantially smaller space requirement in comparison to conventional devices.

10 5. The cycle times for the individual inspection steps do not include any inactive waiting times that would otherwise be necessary for cessation of vibrations of the moved components. Furthermore, the cycle time is also not impaired by the maximum acceleration or delay to be maintained.

15 6. High components and those with an unfavorable center of mass do not present a problem with respect to the mechanical stability of the soldered joints.

20 6. In comparison to the device known from US Patent No. 5 259 012, the range of the board assemblies to be examined is greater. For example, components with a length in the range of 70 to 500 mm, a width in the range of 50 to 500 mm, and a board assembly thickness of 0.5 to 3 mm can be examined with a device according to the invention without previously undertaking adaptations of the measuring geometry. Furthermore, inspections on an inspection surface of 500 x 500 mm are possible with the device according to the invention, where the test window inspected in each inspection has a size of approximately 6.2 cm².

25 7. According to the present invention, a commercially available microfocus X-ray tube with a focal spot diameter of approximately 20 to 40 µm can be used. Neither a large and expensive X-ray tube as is necessary in, for example, the device described in US Patent No. 5 259 012 nor does it require require the complicated control device of such
30 an X-ray tube. Furthermore, no vacuum pumps or cooling are necessary for the X-ray beam tube used for the device according to the present invention.

8. As will be explained further below with reference to an example, it is possible with the aid of the device according to the invention to examine individual components of a printed circuit board three-dimensionally.

5 So that the X-ray beam detector can be moved easily, it preferably has a low mass. According to a preferred embodiment of the invention, the X-ray beam detector is a very high-resolution taper to which a high-resolution CCD chip is attached. For converting the received X-ray beam into visible light, the detector further includes a scintillator. According to the present invention, the detector is preferably a high resolution detector,
10 i.e., at a size of 35 mm x 35 mm it has approximately 1000 x 1000 pixels. Because of its high resolution, the detector can be arranged directly under the board assembly at a distance not exceeding approximately 5 cm. Thus, the diameter of the X-ray beam contacting the test object is only enlarged to a limited degree. Because of the high resolution of the detector, however, the accuracy of the inspection is not impaired by this.
15 By using this special detector, the device according to the invention can be constructed even more compactly.

 Because of this construction, it is not necessary for the X-ray beam source to emit an X-ray beam with only a small focal spot diameter. According to the invention,
20 microfocus tubes with a focal spot diameter of approximately 20 μm to 40 μm produce a satisfactory image sharpness. The use of X-ray beam tubes with enlarged focal spot diameters is advantageous because such an X-ray beam tube emits more photons and thus allows for a better S/N ratio and a better image quality.

25 According to the present invention, the X-ray tube itself and the high-voltage element that contains the power supply for providing the X-ray acceleration voltage, which typically lies in a range from approx. 10 to 100 kV, are moved during the movement of the X-ray source while the control device for changing the operating voltage or the output is housed in the control box so as to be immovable.

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 Because the X-ray beam tube and the detector, which are the same components

in each measurement, are moved, the adaptation of the movement components for the X-ray beam tube and the detector has to be performed once. The adaptation takes place according to known calibration processes.

5 The present invention is described in greater detail in the following with reference to the accompanying drawings.

Fig. 1 shows a schematic view of the device according to the invention for explaining the principle of the invention.

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Fig. 2 shows the use of the device according to the invention for recording oblique projections applied to the three-dimensional evaluation of the test objects.

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Fig. 1 shows a schematic view of a first embodiment of the present invention. In Fig. 1, reference number 1 refers to an X-ray beam tube, reference number 2 refers to an X-ray beam detector, reference number 3 refers to a board assembly to be examined that is loaded with components 4. The X-ray beam tube is mounted in a moveable housing and can be moved in the X and Y directions.

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The device shown in Fig. 1 is used as an example of a completely automated 100% X-ray inspection of soldered joints on printed circuit boards as well as on printed joint assemblies.

25

The board assembly 3 is secured to a housing and is moved into the examination chamber sufficiently slowly that the forces acting during this process do not cause any damage to the soldered joints. Then the board assembly 3 is positioned stationarily so that it is not moved any more during the soldered joint inspection. For recording any section of the board assembly in the area to be examined, the X-ray beam tube 1 and the detector 2 are moved parallel to one another in the X and Y directions. The detector unit 2 includes a camera system that is not shown here. During the examination process, the corresponding area of the board assembly 3 is illuminated by X-ray beams and the

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absorbed X-ray beams are converted to visible light by the detector. With the aid of a camera system, the X-ray image is recorded and transmitted to a computing device for evaluation.

5 At the beginning of the soldered joint examination, the loading data of the board assembly are retrieved. The loading data (CAD data) define which component is placed at which position and at what angle of rotation. On the basis of this information and taking into consideration the object resolution, it is possible for each recorded X-ray image to determine precisely where a soldered joint of a component is shown in the X-ray
10 image.

 In the computing device, with the aid of the underlying CAD data, the soldered joints appearing in the image are "cut out" and subsequently transmitted to the image analysis unit.

15 Depending on the loading density of a board assembly, some thousand soldered joints are located on each panel of a board assembly. Theoretically, the technician who compiles the examination program for this component would have to assign testing parameters to each soldered joint. This interactive input is not only time-consuming but
20 also very susceptible to error. In particular, it is very difficult to find the correct adjustments (tolerance, threshold, etc.) that guarantee a minimal occurrence of pseudo-slippage. Therefore, according to a preferred embodiment of the present invention, the system is programmed in such a way that it finds the parameter itself, which saves a significant amount of time and requires no interaction on the part of the user. In this
25 embodiment, the threshold/tolerance determination is very close to reality and is only improved in a few places by the user.

 Thus, according to this preferred embodiment, two modes are available for the subsequent image evaluation for inspection of soldered joints.

30

Learning Mode

5 A set of testing algorithms to be used is transferred to the image analysis unit by means of the image buffer. With the aid of these algorithms, a characteristic vector is generated for the individual soldered joint. This characteristic vector describes only this soldered joint and no other soldered joints of the same type. This characteristic vector is optimized with the vectors of the same soldered joint of further boards so that in an ideal situation, after several defect-free soldered joints have been examined, a characteristic vector has been generated that statistically represents a defect-free soldered joint. This characteristic vector can be stored in a testing database by pad and components, so that the learning process can be omitted with new boards to be tested that contain components of the same type. These vectors are also stored in the component-specific board assembly data file.

Testing Mode

15 In the testing mode, the image evaluation unit of the pad image buffer, the set of testing algorithms, and the learned characteristic vectors are transmitted with permissible variations.

20 When the characteristic vector obtained correlates with the learned vector within the predetermined tolerances, the soldered joint is classified as defect-free, otherwise it is classified as defective.

25 Here, the set of testing algorithms is not provided in a fixed manner and it need not be limited with respect to components. The user can also freely add new algorithms into the system and incorporate them in or exclude them from inspections as needed.

30 The following defects can be localized in the board assembled by the testing process used. On the one hand, a faulty soldering quality such as, for example, cavities, blow-outs, sunken spots, poor and/or no wetting of components, lack of contact on the

component, too much or too little solder, solder bridges (short circuit), tin nodules and other tin residue (e.g., between conductors or connections) and, on the other hand, defective loading quality, such as, for example, a missing component, a component that is warped or displaced, a component placed too high, leads bent or displaced. The types of components that can be examined are THT (Through Hole Technology), SMD (Surface Mounted Devices), and BGA (Ball Grid Array).

In order to record another section of the board assembly in the area to be examined, the X-ray beam tube 1 and the detector 2 are again moved parallel to one another in the X and Y directions while the board assembly remains stationary. These processes are conducted until the entire section of the board assembly 3 to be tested has been examined. The position recognition of the individual sections of the board assembly is effected by means of an automatic evaluation of the positions of pass marks and/or plated-through holes.

In the device according to the invention, it is also possible to move the X-ray beam tube 1 and the X-ray beam detector 2 in opposite directions from one another in order to cause a diagonal penetration as shown in Fig. 2. Thus, cross-sectional images can be made that are suitable for three-dimensional layer image recording in the framework of a tomosynthesis process. The distance measurements necessary for the tomosynthesis process preferably are performed by means of a laser triangulator.

Because the board assembly is not moved during the examination process, component-specific weights do not have any effect in the form of up-and-down vibrations of the board assembly. Thus, on the one hand, no waiting times for cessation of vibrations are necessary and, on the other hand, distance measurements to the surface of the board assembly are conducted with increased accuracy. This increased accuracy of the distance measurements has an especially advantageous effect in the three-dimensional tomosynthesis process.

After the end of the examination process, the board assembly 3 is removed from

the examination chamber sufficiently slowly that the forces acting during the process do not cause any damage to the soldered joints.

5 According to the present invention, an additional mechanism can be provided for moving the detector in the Z direction (parallel to the surface normal of the assembly). Thus, a component-specific adaptation of the object resolution can be achieved. This leads to an optimization of the attainable examination speed in two-dimensional as well as three-dimensional inspection because, for example, assemblies and components with a coarser soldered joint structure can be examined with a correspondingly higher surface
10 throughput.

Claims

1. Device for inspecting test objects (3) having

- an X-ray beam tube (1) with a small field of view in relation to the horizontal
5 extent of the area of the test object to be examined,

- a detector (2) with a small field of view in relation to the horizontal extent of the
area to be examined,

characterized in that the device is constructed in such a way that the test object (3) is
stationary during the inspection process while the X-ray beam tube (1) and the detector
10 (2) are arranged moveably within the X-Y plane for inspecting the entire area of the test
object to be examined.

2. Device as in claim 1, characterized in that the test object (3) is attached to a carrier that
remains stationary during the inspection of the test object.

3. Device as in claim 1 or 2, further characterized in that a computing device is connected
to the detector (2).

4. Device as in claim 3, further characterized in that an analysis unit is connected to the
computing device.

5. Device as in one of claims 1 to 4, characterized in that the X-ray beam tube (1) is a
microfocus tube with a focal spot diameter of 10 to 40 μm .

6. Device as in one of claims 1 to 5, characterized in that the detector (2) is a CCD chip
arranged on a taper.

7. Device as in one of claims 1 to 6, characterized in that it is suitable for two-dimensional
examination of test objects (3).

8. Device as in claim 7, characterized in that it is suitable for three-dimensional examination of test objects (3).

5 9. Device as in one of claims 1 to 8, characterized in that the test objects are printed circuit boards and/or loaded printed board assemblies.

10 10. Use of the device as in one of claims 1 to 9 for X-ray inspection of soldered joints on printed circuit boards and/or loaded printed board assemblies.

11. Use as in claim 10 for fully automated 100% X-ray inspection of soldered joints on printed circuit boards and/or loaded printed board assemblies.

15 12. Use as in claim 10, if dependent upon claim 4, characterized in that a set of testing algorithms is transmitted to the image analysis unit in learning mode and, with the aid of these algorithms, a characteristic vector is generated for an individual soldered joint that, with the vectors of this soldered joint from other printed circuit boards and/or loaded printed board assemblies, will be optimized so that the resulting characteristic vector will statistically represent a defect-free soldered joint.

20 13. Use as in claim 12, characterized in that, in testing mode a pad image buffer, the set of testing algorithms, and the learned characteristic vectors with tolerances are transmitted to the image analysis unit, and in order to test a soldered joint, the correlation between the learned characteristic vectors with tolerances and the soldered joint under test is determined.

Abstract

The invention relates to a device for inspecting test objects, comprising an X-ray tube which has a small field of view compared to the horizontal dimension of the test object being inspected, and a detector which has a small field of view compared to the horizontal extent of the test object being examined. The X-ray tube and the detector are moved within the X-Y plane so that the test object remains in a fixed position during the inspection process and the whole of the area to be tested can be inspected. The device according to the invention presents advantages when used for fully-automatic, 100% X-ray inspection of soldered joints on printed circuit boards.

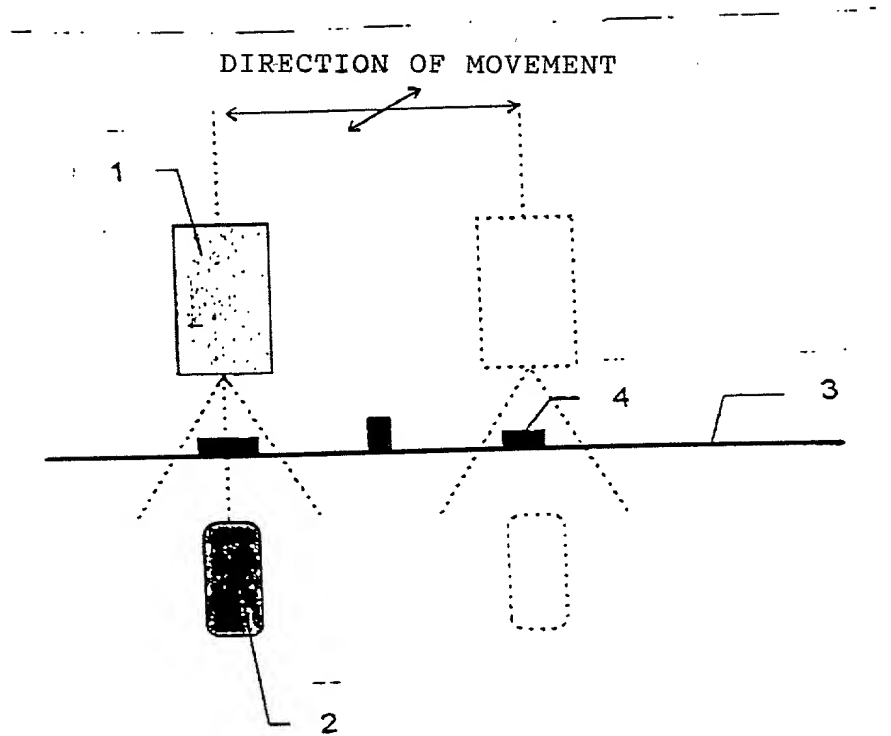


FIG. 1

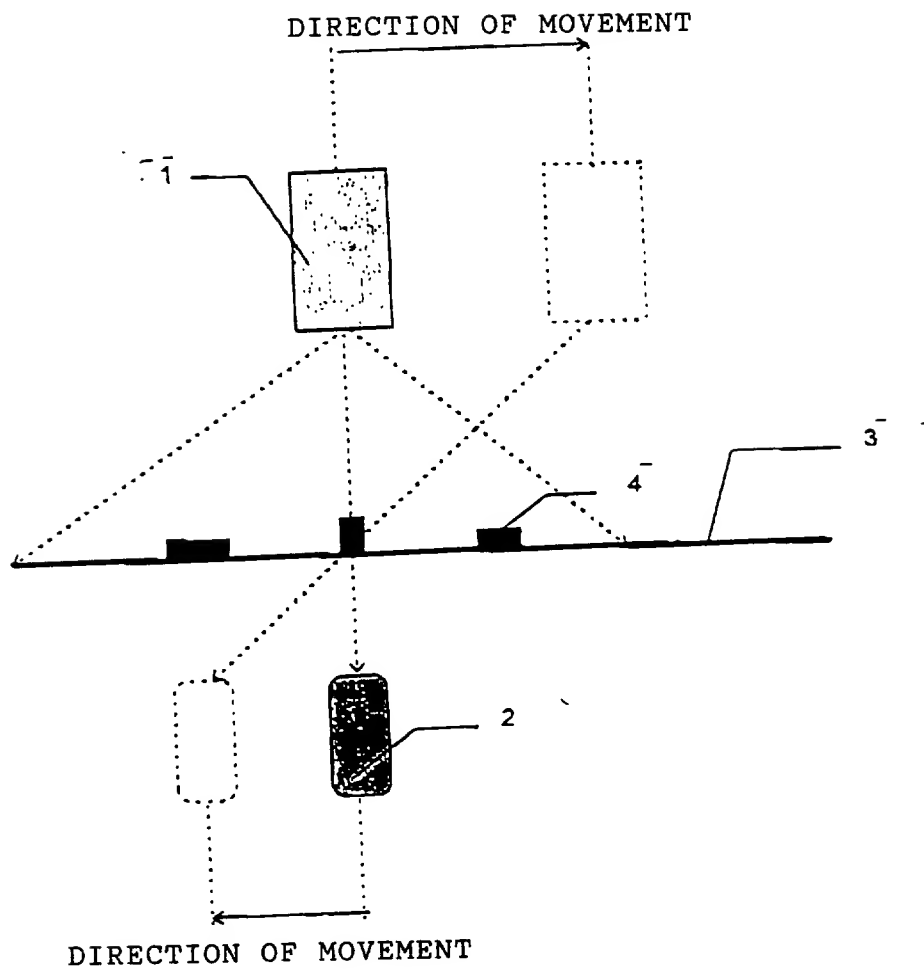


FIG. 2

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY
(Includes Reference to PCT International Applications)

Attorney's Docket Number
P18477

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

DEVICE FOR INSPECTING TEST OBJECTS AND THE USE THEREOF

the specification of which (check only one item below):

☐ is attached hereto.

☐ was filed as United States applications

Serial No. _____

on _____

and was amended

on _____ (if applicable).

☒ was filed as PCT international application

Number PCT/DE97/02024

on September 9, 1997

and was amended under PCT Article 19

on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, §1.56

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:

COUNTRY (if PCT, indicate "PCT")	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
Germany	197 15 502.2	April 14, 1997	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO
			<input type="checkbox"/> YES <input type="checkbox"/> NO
			<input type="checkbox"/> YES <input type="checkbox"/> NO
			<input type="checkbox"/> YES <input type="checkbox"/> NO
			<input type="checkbox"/> YES <input type="checkbox"/> NO

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P.3 NO.028

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SEP. 15, 1999 6:52PM

Combined Declaration For Patent Application and Power of Attorney (Continued)
(Includes Reference to PCT International Applications)ATTORNEY'S DOCKET NUMBER
P18477

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s) or PCT international application(s) designation the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application.

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. 120:

U.S. APPLICATIONS		STATUS (Check One)		
U.S. APPLICATION NUMBER	U.S. FILING DATE	PATENT	PENDING	ABANDONED
PCT APPLICATIONS DESIGNATING THE U.S.				
PCT APPLICATION NO.	PCT FILING DATE	U.S. SERIAL NUMBER ASSIGNED (IF ANY)		

The undersigned hereby authorizes the U.S. attorney or agent named herein to accept and follow instructions from either his foreign patent agent or corporate representative, if any, as to any action to be taken in the Patent and Trademark Office regarding this application without direct communication between the U.S. attorney or agent and the undersigned. In the event of a change in the persons from whom instructions may be taken, the U.S. attorney or agent named herein will be so notified by the undersigned.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the attorney(s) and/or agents(s) associated with the Customer Number provided below to prosecute this application and transact all business in the Patent and Trademark Office connected therewith, and direct that all correspondence be addressed to that Customer Number:

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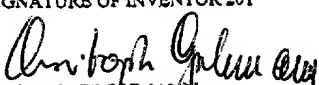
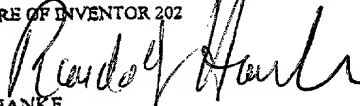
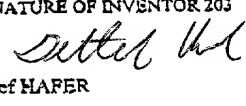
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	POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE & ZIP CODE/COUNTRY
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

SIGNATURE OF INVENTOR 201  Christoph GROHMANN	SIGNATURE OF INVENTOR 202  Randolf HANKE	SIGNATURE OF INVENTOR 203  Detlef HAFER
DATE 30. Sep. 1999	DATE 29.09.99	DATE 30. Sep. 99

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